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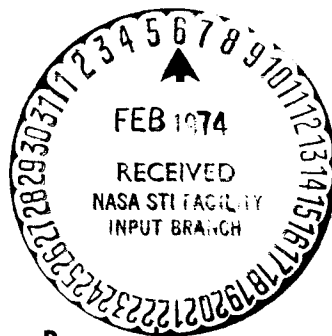
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August 28, 1969

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## CSM BATTERY CHARGER MODEL



Guidance and Performance Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER  
HOUSTON, TEXAS



(NASA-TM-X-69690) CSM BATTERY CHARGER  
MODEL (NASA) 41 p

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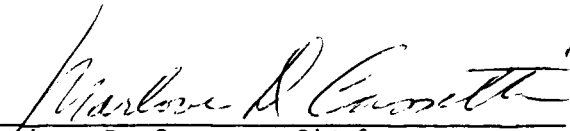
CSM BATTERY CHARGER MODEL

By James McClellan and R. E. Stokes  
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## CSM BATTERY CHARGER MODEL

By James McClellan and R. E. Stokes

### 1.0 SUMMARY AND INTRODUCTION

The purpose of this note is to present the design concept, assumptions, logic flow chart, program listing, and a sample case of the CSM battery charger model. Basically, the model simulates the battery charger during the charge cycle of the entry and postlanding batteries. The model is to be used in the CSM SEENA program so that more accurate CSM entry and postlanding battery power profiles may be generated. The model will also be used to simulate the CSM battery charger in the AAP EPS program.

## 2.0 SYMBOLS

A, B, C, E, F	tables of data for charge rate curve
AF	degradation factor
A-h	ampere hours
AHD	amp-hours discharged from Batt I
AHS(I)	amp-hours present in Batt I
AHST	present amp-hour status
AMP(I)	amps into Batt I
Batt I	CSM entry and postlanding batteries
CALC	intermediate variable used for comparison only
CP	intermediate variable (%) read from C table and used to calculate C ( $C = CP * B$ )
CSTS	$CST1 + CST2$
CST1	area under charge rate curve from 0 to E
CST2	area under charge rate curve from E to F
DELCH	delta charge, charge under curve from TA to T
FT	intermediate variable read from F table and used to calculate F ( $F = FT + E$ )
FULCH	full recharging capability of Batt I (near 40 for the first five recharges)
JBATT(I)	0 if Batt I is OFF 1 if Batt I is ON
NCH	number of times the charger has been used on Batt I
NCHRG(I)	number of times the charger has been used on Batt I
ONAH(I)	amp-hour status of Batt I at ON-time
ONAHS	amp-hour status at ON-time

ONT	ON time
ONTIM(I)	ground elapsed time (g.e.t.) at which the charger was put on Batt I
PT	present ground elapsed time (g.e.t.)
RE	area under charge rate curve from F to G
SEENA	spacecraft electrical energy network analysis
T	time variable for time axis in charge rate curve ( $T = PT - ONT$ )
TA	time of the last solution relative to the time axis of the charge rate curve
TD(I)	ground elapsed time (g.e.t.) of the last major discharge of Batt I
TLD	time of the last discharge
TLS	time of the last solution
TL(I)	ground elapsed time (g.e.t.) of the last solution for the charger on Batt I
VI	volt-amp characteristic of charger
VOLT(I)	voltage on Batt I
XY1	y-intercept on line segment with slope X1
XY2	y-intercept of line with slope X2
X1	slope of line segment from (O, A) to (E, B)
X2	slope of line segment from (E, B) to (F, C)

### 3.0 BATTERY CHARGER DESCRIPTION

The battery charger is of constant voltage output design. The battery charger is supplied with both a dc voltage source of between 25 to 30 volts and an ac voltage source of 400 Hz three-phase 115 volts to produce a 40-volt output charging EMF. A two-stage differential amplifier, Schmitt trigger, current sensing resistor, and voltage amplifier comprise the battery charger logic network which sets up the initial conditions for the battery charger operation. A switching transistor, current amplifier, sensing resistor, and switching choke complete the basic battery charger circuit. The fundamental circuit logic flow is presented in figure 3-1. When the battery charger is turned on, the first stage of the differential amplifier (comparator) is in the ON mode. The second stage of the comparator would then be in the OFF mode, which in turn sets the first stage of the Schmitt trigger to the ON mode with the second stage off. This circuit configuration produces maximum base drive on the current amplifier which turns the switch transistor on. At this time, the circuitry which permits the charging current to flow into the battery is closed. Charging current flows from the transformer rectifier circuit through the switching transistor, current sensing resistor, and the switching choke. The voltage drop across the current sensing resistor increases as the charging current increases. When the voltage drop reaches a specific level, the second stage of the comparator is switched automatically to the ON mode, and the first stage is switched to the OFF mode. The voltage amplifier in turn is switched off, which reverses the operation mode of the Schmitt trigger. Because the first stage of the Schmitt trigger is off and the second stage is on, the switching transistor is turned off, which interrupts the charging current path. As a result, the electromagnetic field in the choke collapses, discharges into the battery being charged, then passes through the switching diode, and goes through the sensing resistor. As the field in the choke continues to collapse, the EMF in the choke decreases, and the voltage drop across the sensing resistor decreases until the voltage has again reached a specific low level and the comparator mode of operation is reversed (stage 1 is ON, and stage 2 is OFF). The initial conditions have been reset, and one cycle of battery charging has been completed. As a result of a series-connected inductor in the charging circuit, the output current of the charger remains free from variation except for a small amount through the current sensing resistor.

In summary, the battery charger output current is regulated by the sensing resistor until the battery voltage reaches 37.0 volts. At a battery voltage of 37.0 volts, the voltage sensor circuit becomes unbiased and, in conjunction with the sensing resistor, provides a signal for cycling the battery charger. Battery charging is terminated when the battery voltage reaches 39.8 volts.

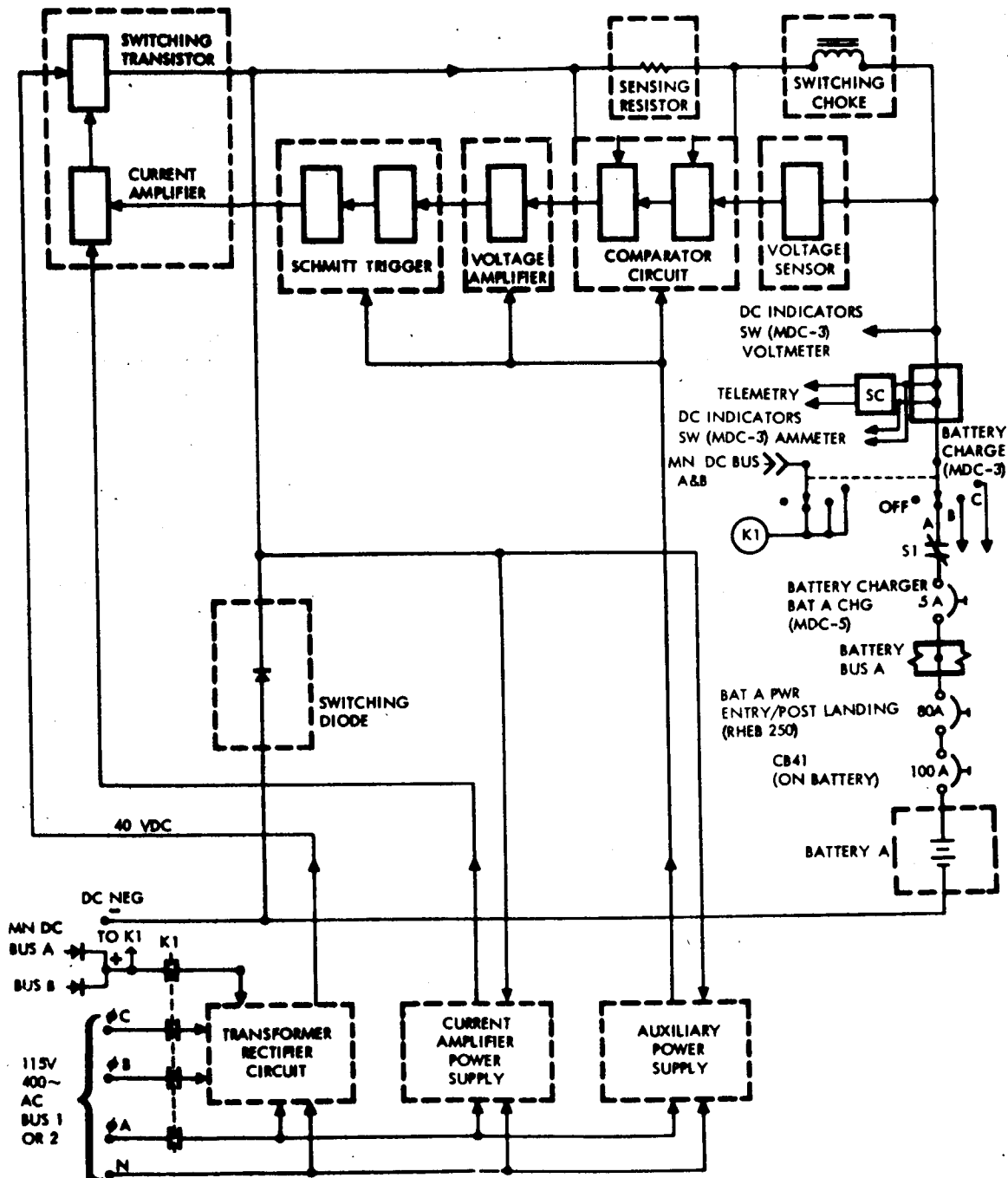


Figure 3-1.- Block diagram of the CSM battery charger circuit.

## 4.0 ASSUMPTIONS AND DESIGN

The battery charger model is an empirical model. It was designed from actual test and performance data obtained from reference 1. The battery charger constraining functions were determined from the actual test data. Various test data trends were noted and are represented in the plots of section 9. A generalized battery charger output curve was determined from the performance data (fig. 4-1). The generalized output curve was broken into three sections so that it could be mathematically manipulated by the initial conditions of the battery being charged. When the initial conditions of the battery are known, the battery charger output characteristic can be calculated. The maximum charge time for 100 percent battery recharge can be determined from the charger output characteristic as well as from the battery charger voltage-current characteristics for any time during the recharge cycle of the battery. The battery also can be recharged in a number of charge periods by calculation of the battery charger characteristic output curve for each recharge period.

The battery charger model is based upon several assumptions which are discussed in this section. After the initial inspection of the data in reference 1, it can be determined that the battery charger recharge capability is a function of three variables: the ampere-hours discharged from the battery, the time from the end of the last battery discharge, and the time from the end of the last battery charge. The effect of the time from the end of the last battery charge is assumed to be an insignificant factor in the battery charger model. A 100 percent battery charger efficiency is assumed; that is, all of the energy supplied to the battery by the battery charger is used to reenergize the depleted battery. The maximum ampere-hour capacity of the battery is assumed to decrease by 10 percent after five cycles of battery charge and recharge. This decrease simulates battery degradation after several usage cycles. Battery loads of less than 1 ampere per battery will not be considered when the time from the end of the last discharge is being determined. The battery charger input power does not vary as a function of output current in the SEENA CSM program. The AAP CSM battery charger model will have an input power that varies with fluctuations in output charge current. The battery charger input voltage-current levels are indicated in figure 4-2 as a function of the output or charging current.

The general battery charger output or charging curve is shown in figure 4-2. The charger current is plotted against the time the charger is on the battery. All the coordinates except 0.4 can be obtained from the various plots in section 9. The 0.4-ampere coordinate is a test data value which guarantees complete battery recharge. Coordinates A



and B are functions of the ampere-hours discharged from the battery and of the time from the end of the last battery discharge. All the data necessary for these coordinates are given in figures 9-1 and 9-2. Coordinate C is a function of the ampere-hours discharged from the battery and is illustrated in figure 9-3. The data in figure 9-3 are expressed as a factor that is multiplied by the value of coordinate B to obtain coordinate C. Coordinate E is a function of the time from the last discharge. The rise time of the peak current, which is coordinate E, is presented in figure 9-4 as a function of the time from the end of the last discharge. Coordinate F is presented in figure 9-5 as a function of ampere-hours discharged from the battery. The time given on the vertical scale of figure 9-5 is relative to coordinate E. Coordinate G is a function of coordinates A, B, C, E, F, and the total ampere-hours needed to completely recharge the battery.

$$G = \frac{2[A-h \text{ needed to completely recharge the battery}] + F}{C + 0.4}$$

Because the battery charger output curve can be determined, the effect of the charger on the battery for any period of time can be determined.

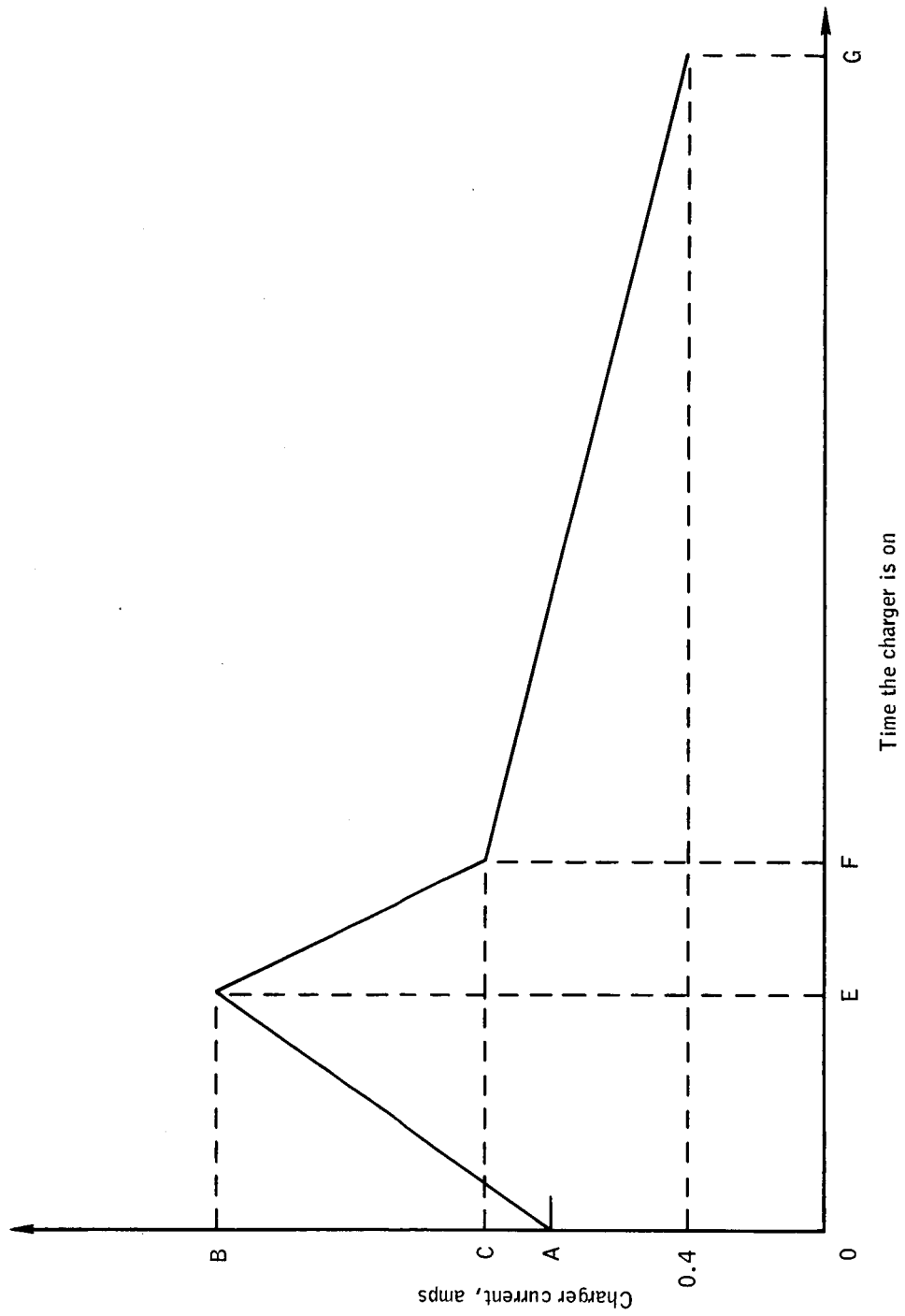


Figure 4-1.- Battery charger general recharge rate curve.

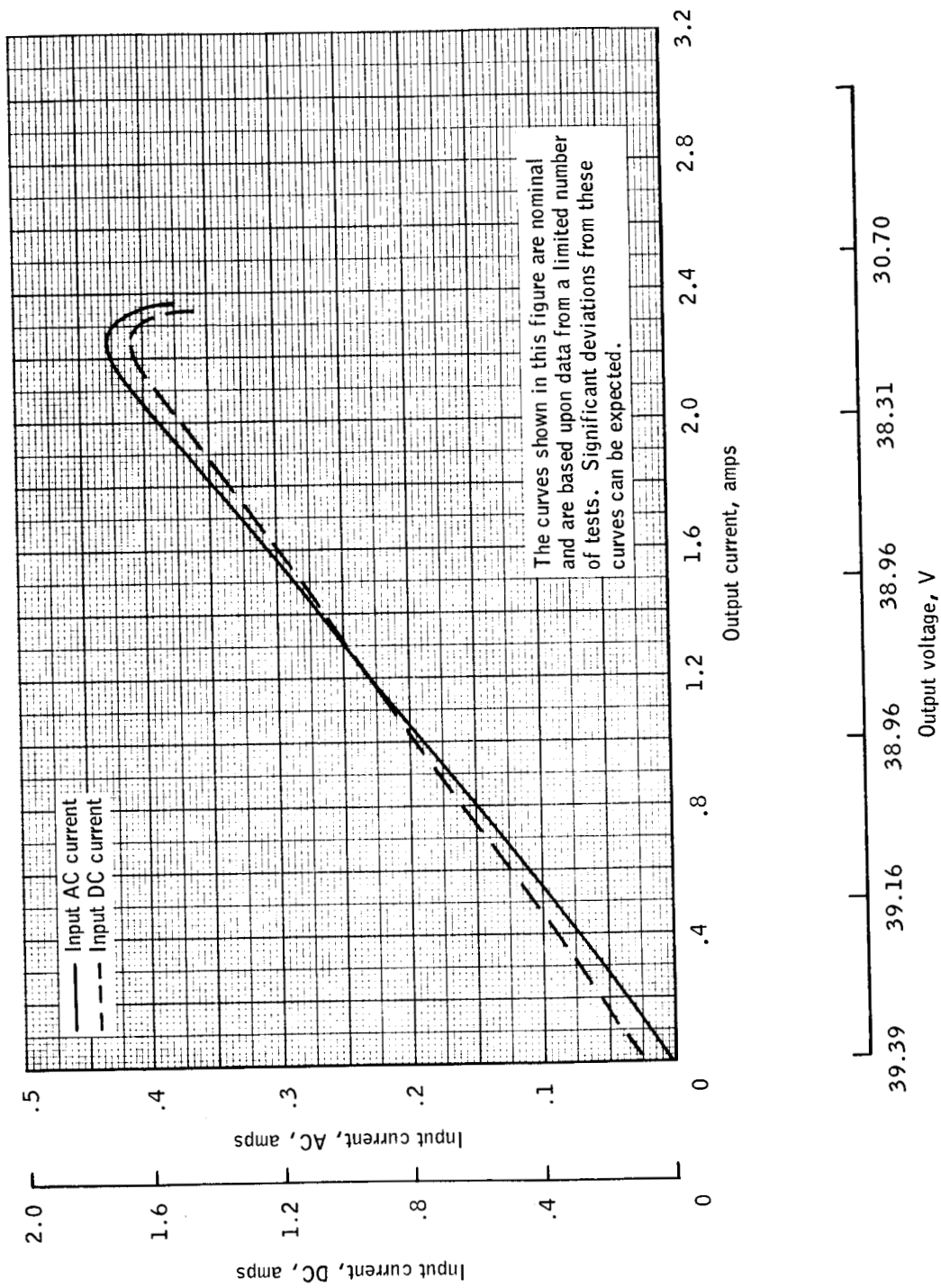


Figure 4-2.- Nominal battery charger input/output characteristics.

## 5.0 COMPUTER PROGRAM DESCRIPTION

The program flow is divided into six major sections in the general flow diagram. These sections emphasize the overall operation of the model from the inputs, through the checks and calculations, and finally to the update and outputs to the main program. Each section will be considered individually in the discussion which follows.

The inputs to the battery charger model consist of three types.

a. Data curves: these six curves have been extracted from test data on the charger and provide the program with the necessary information to calculate the characteristics of the battery.

b. Status of the batteries: this vital information is stored in arrays TL, AHS, TD, ONAH, ONTIM.

c. Charger ON: These data indicate which battery is being charged and at what time a solution point is desired. The form of this input is arranged in a card as follows.

	Columns
	12 14 16
Present	Battery
time	A B C
Cols 1-10	

"1" if charger is on

The program reads the information in columns 12, 14, and 16 into a three-element array JBATT(3). Then a DO loop is used to compare each element of JBATT to 1. For example, if Batt A is being charged, then JBATT(1) is equal to 1 and control leaves the DO loop; all status information on battery A would be transferred into nonsubscripted names ONT, TLD, TLS, NCH, ONAHS, AHST. At this time, the program checks to see if this is the first time solution during the recharge cycle. If so, a counter that registers the number of charges is incremented. Then the program checks to see how many times battery A has been recharged. If it has been charged more than five times, then an adjustment is made so that the battery can charge back up to only 90 percent of the original charge, which is 36 A-h. This maximum charge is called FULCH in the program.

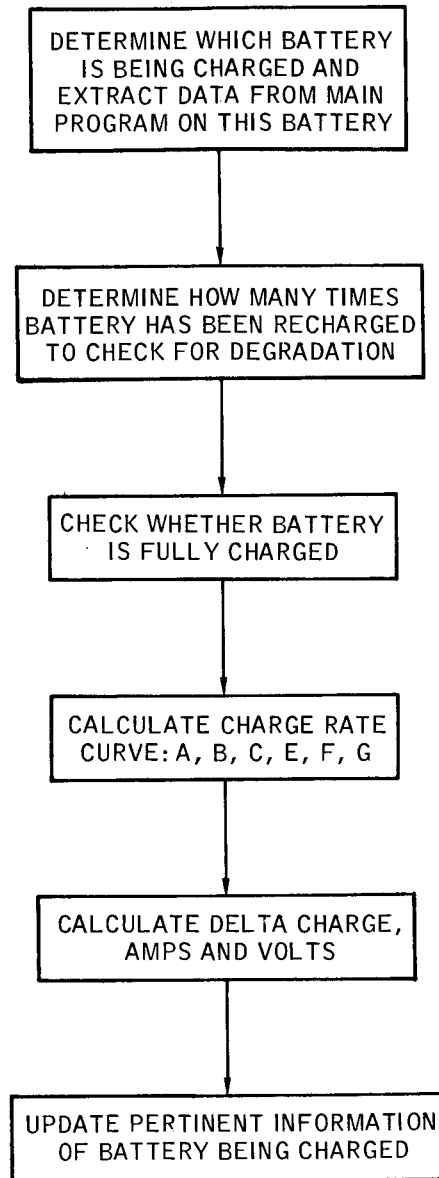
Next, the program checks to see if battery A is fully charged. This check is made by a comparison of AHST + 0.001 to FULCH. The 0.001 is added to insure that the test does not fail in an insignificant decimal place.

Then the program proceeds to the calculation phase. First, the charge rate curve is calculated by interpolation of the curves A, B, C, E, and F which are functions of TLD and AHD. Then by integration from the time of last solution to the present time, the delta charge is calculated. Two checks are made to insure that the charge does not exceed the full charge and that the charger current is 0.4 amps at full charge. The program examines the amount of charge necessary to return to full charge and checks to see that the time to obtain this charge is greater than F. If not, the program will force a solution to come at full charge and 0.4 amps. Otherwise, the manner in which the time G is calculated will insure that the full charge will come at 0.4 amps.

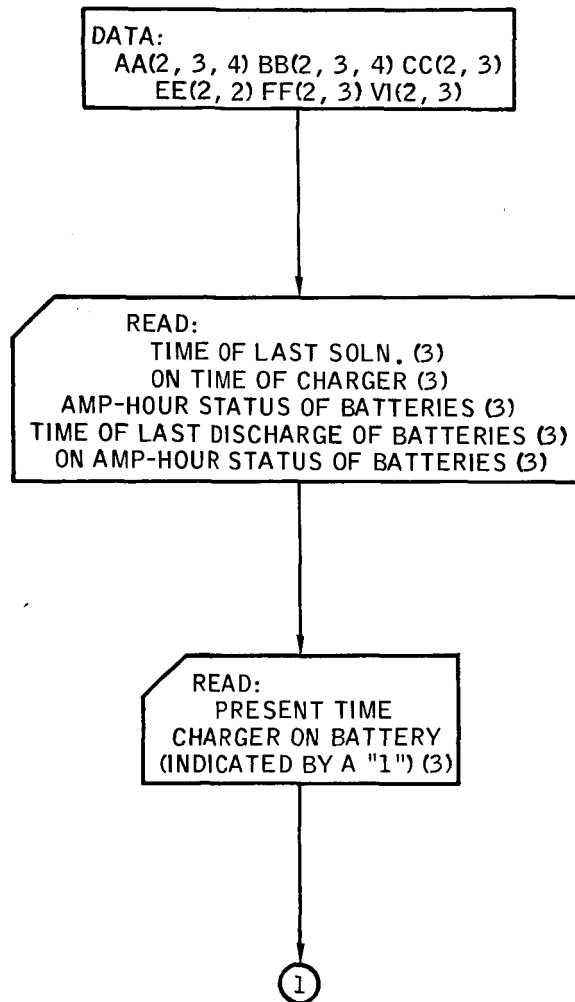
The output voltage is calculated by interpolation of the volt-amp characteristic curve of the charger. Then all pertinent information concerning the battery being charged is updated and stored for usage in the main program.

## 6.0 FLOWCHART

The battery charger program flow chart is presented in this section.

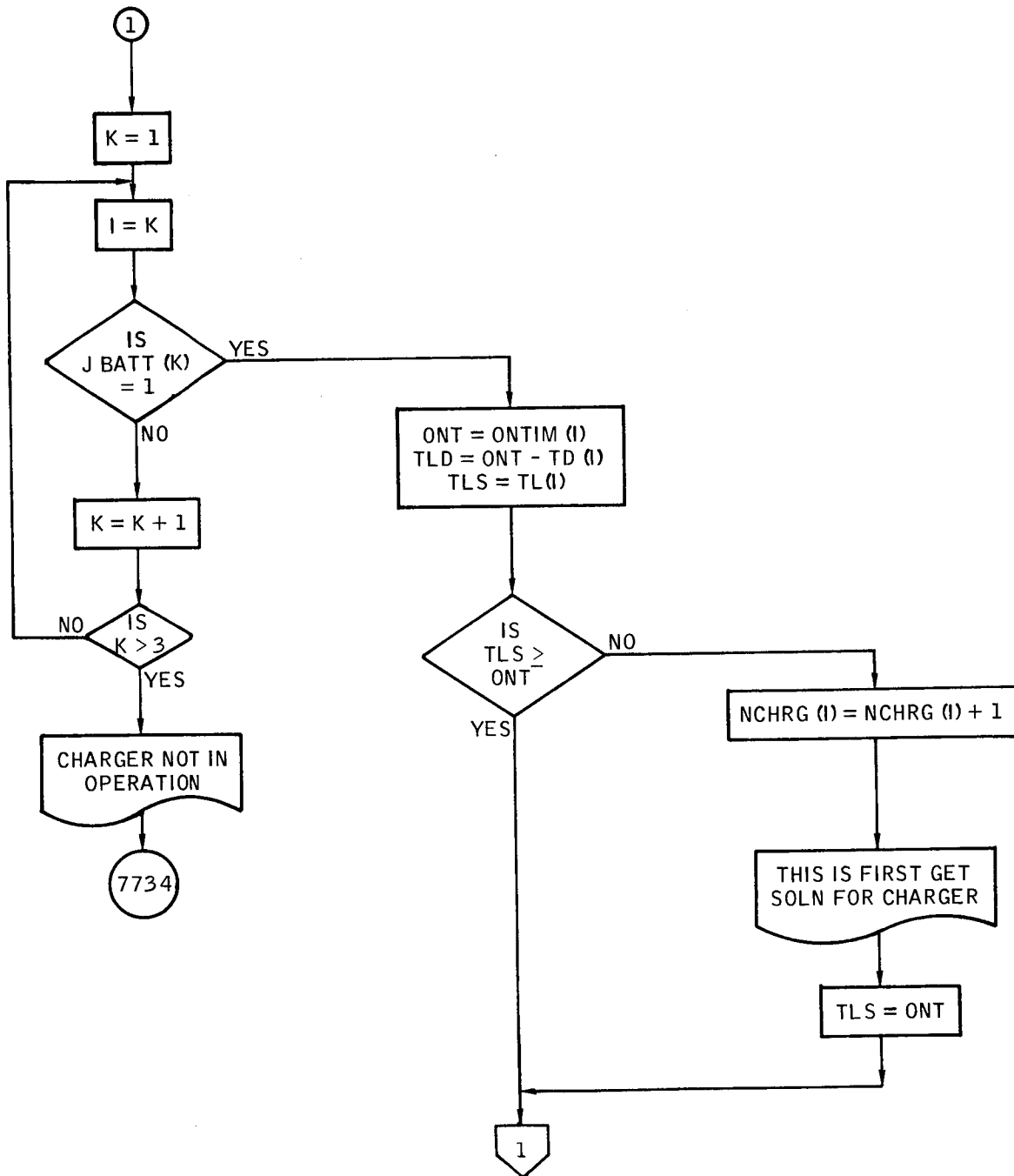


GENERAL FLOW

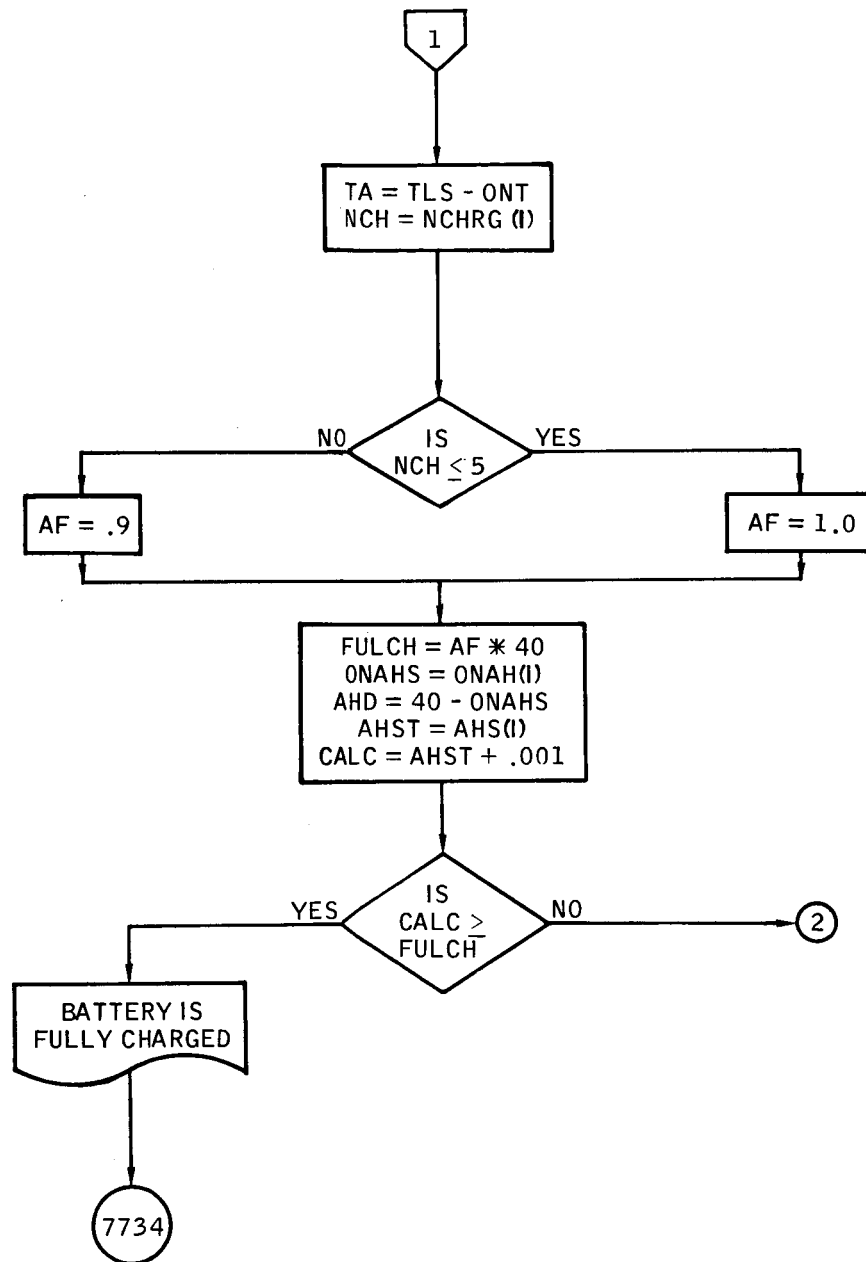


Flow Chart.- Inputs.

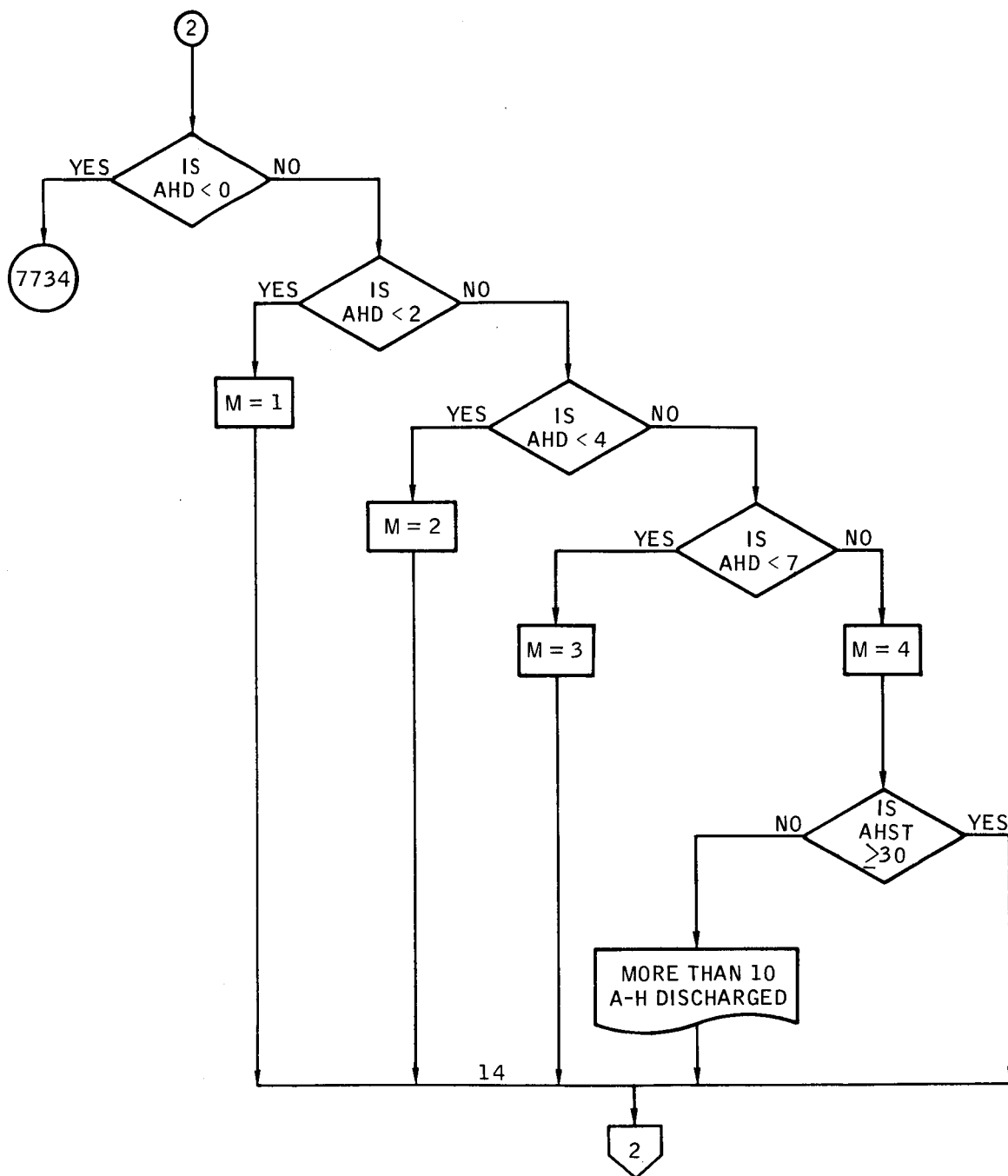




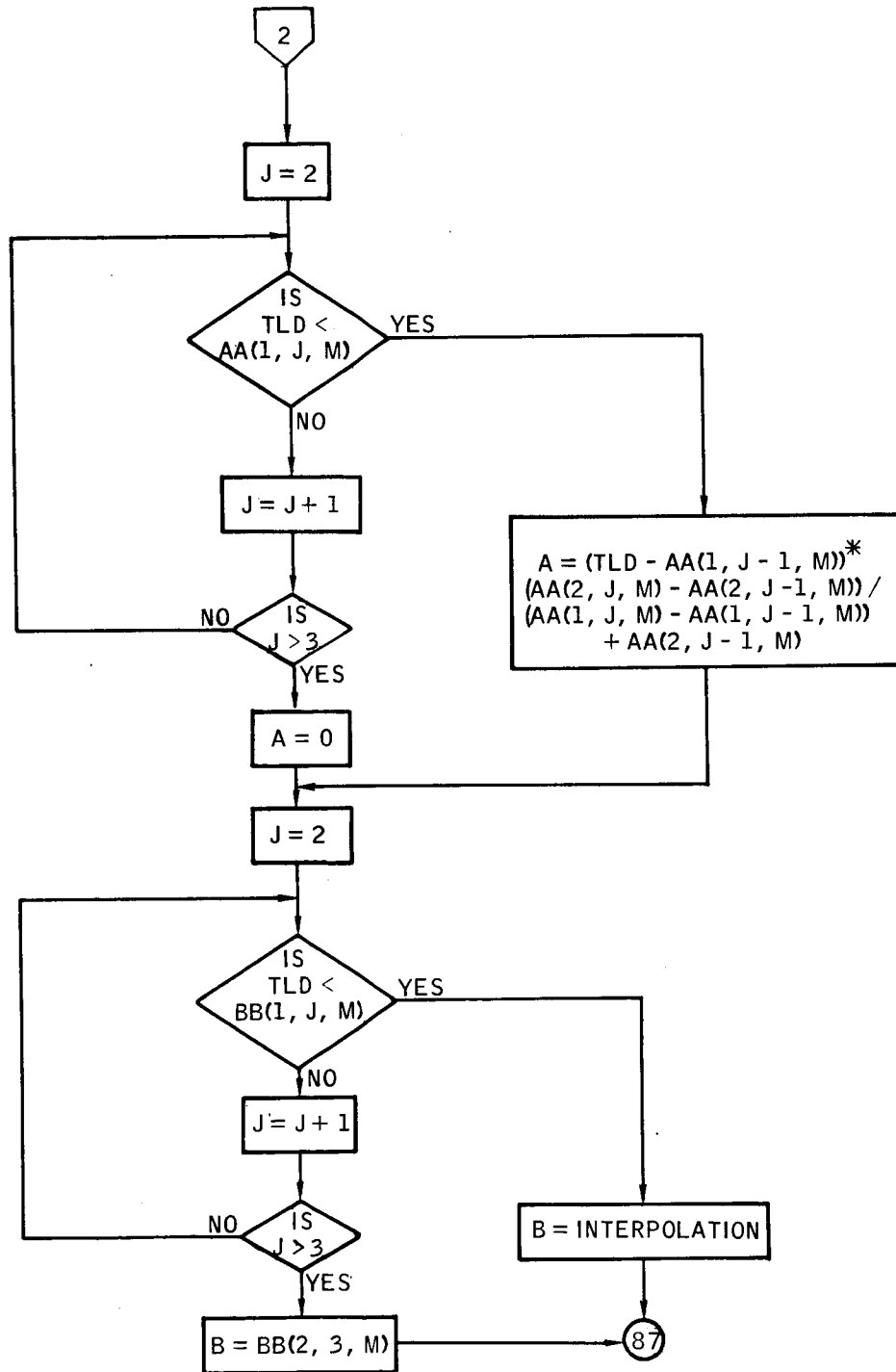
Flow Chart . - Continued.



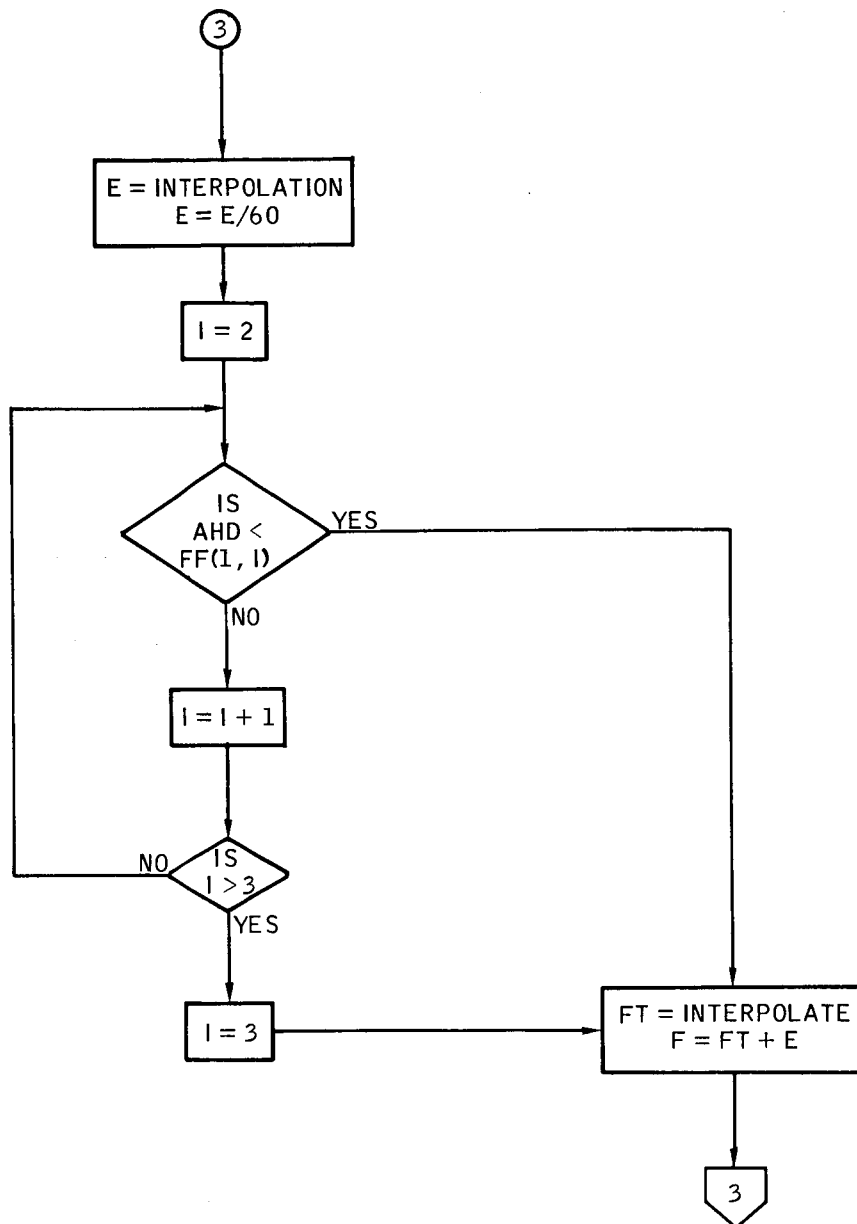
Flow Chart . - Continued.



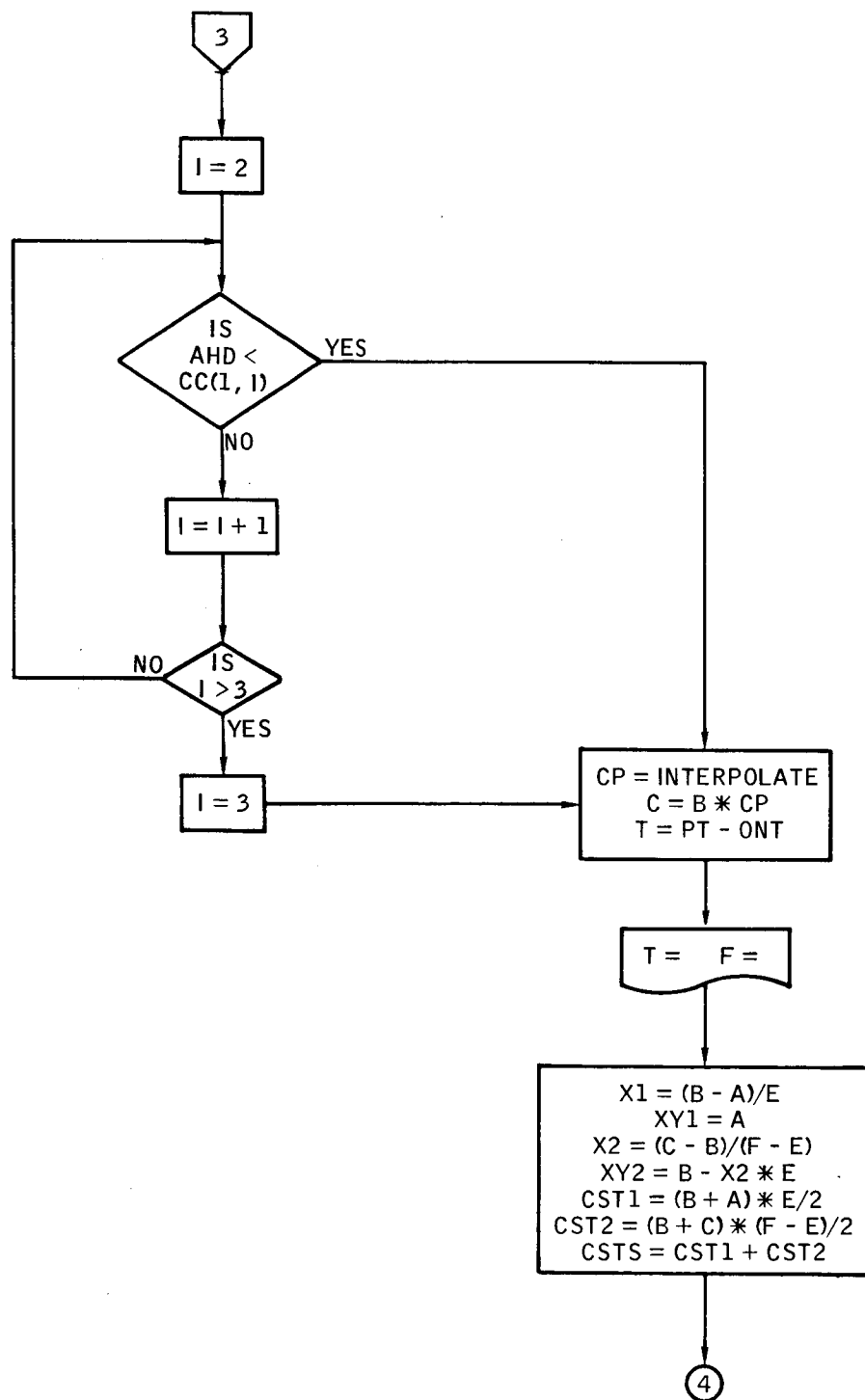
Flow Chart.- Continued.



Flow Chart. - Continued.

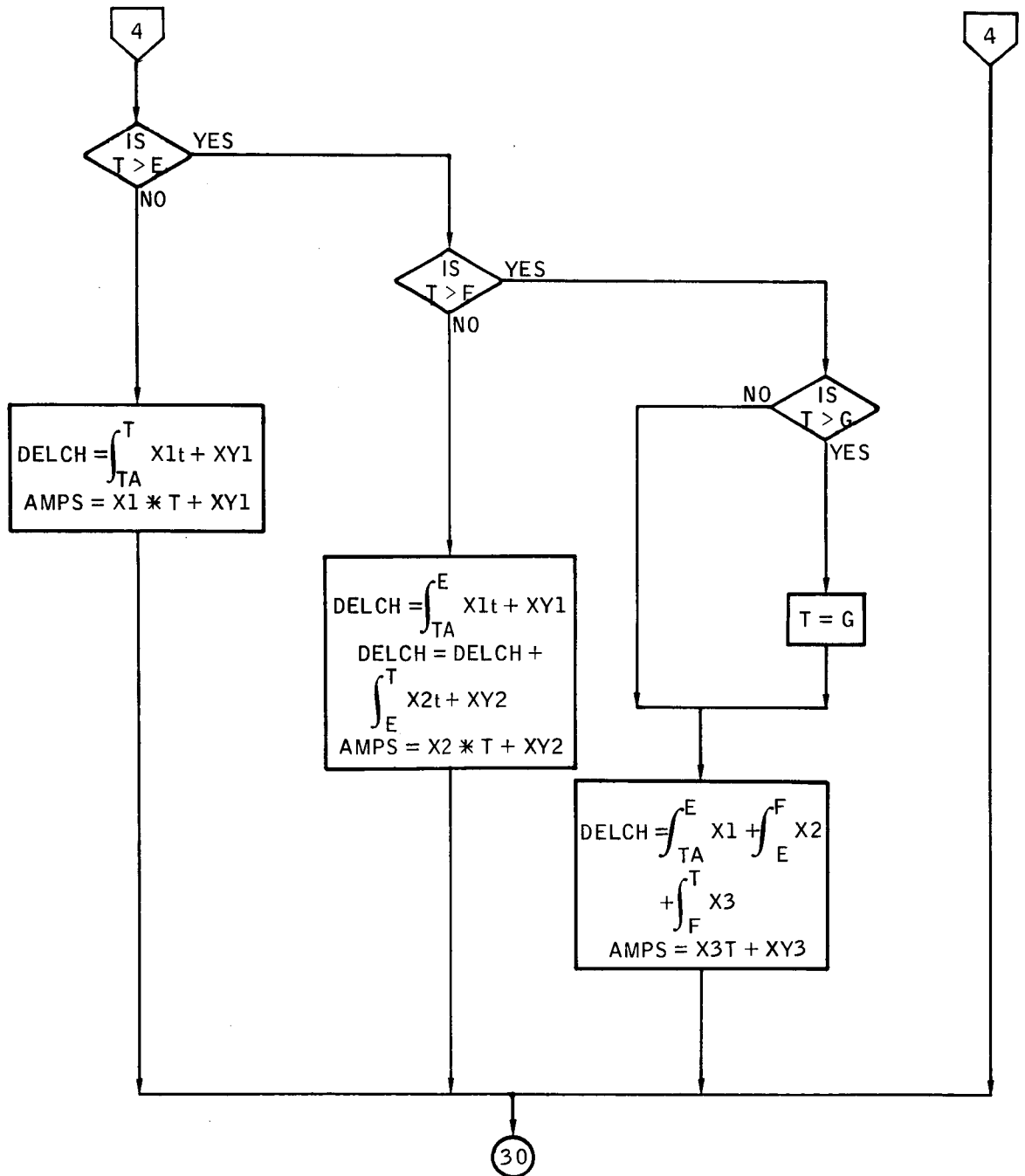


Flow Chart . - Continued.



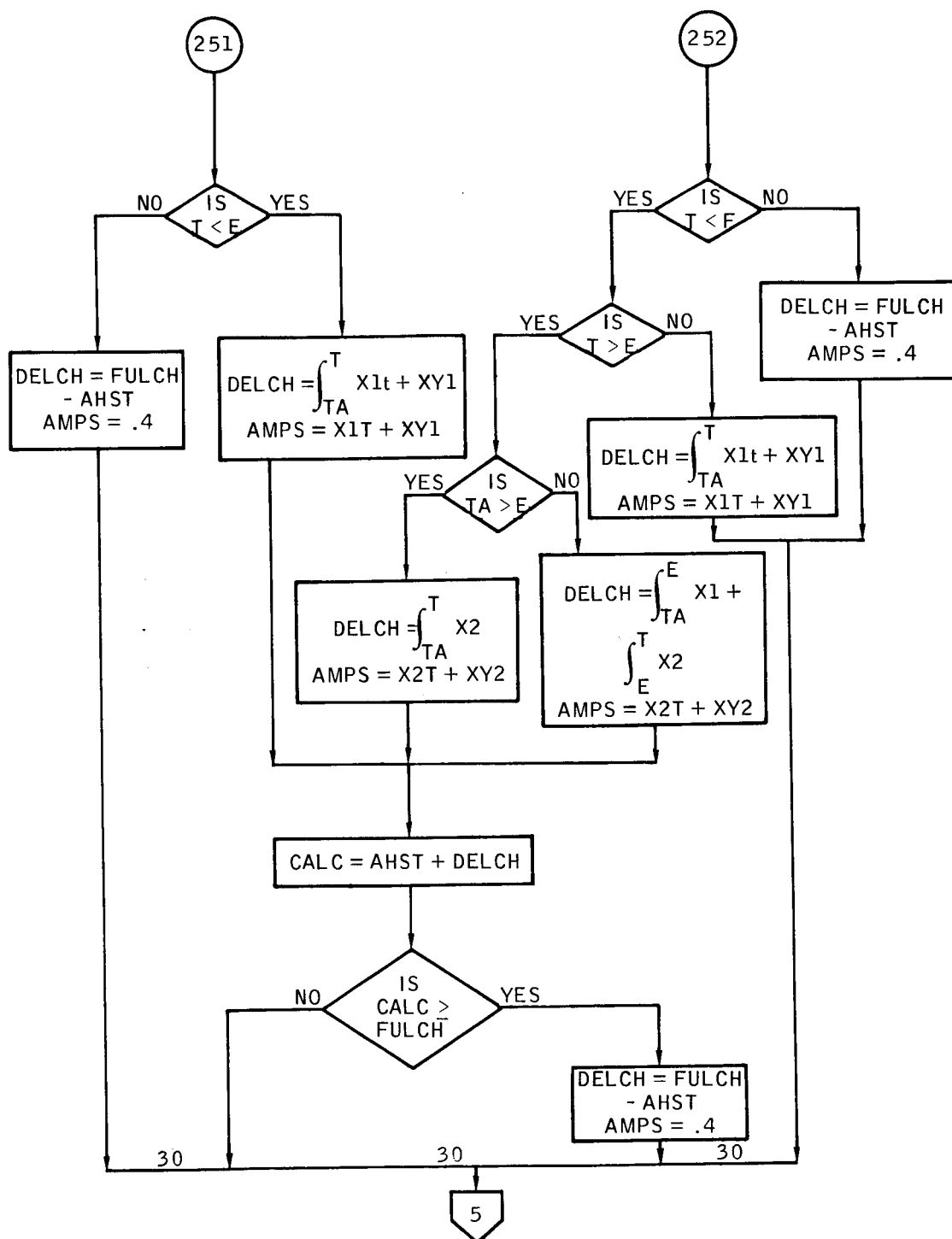
Flow Chart . - Continued.

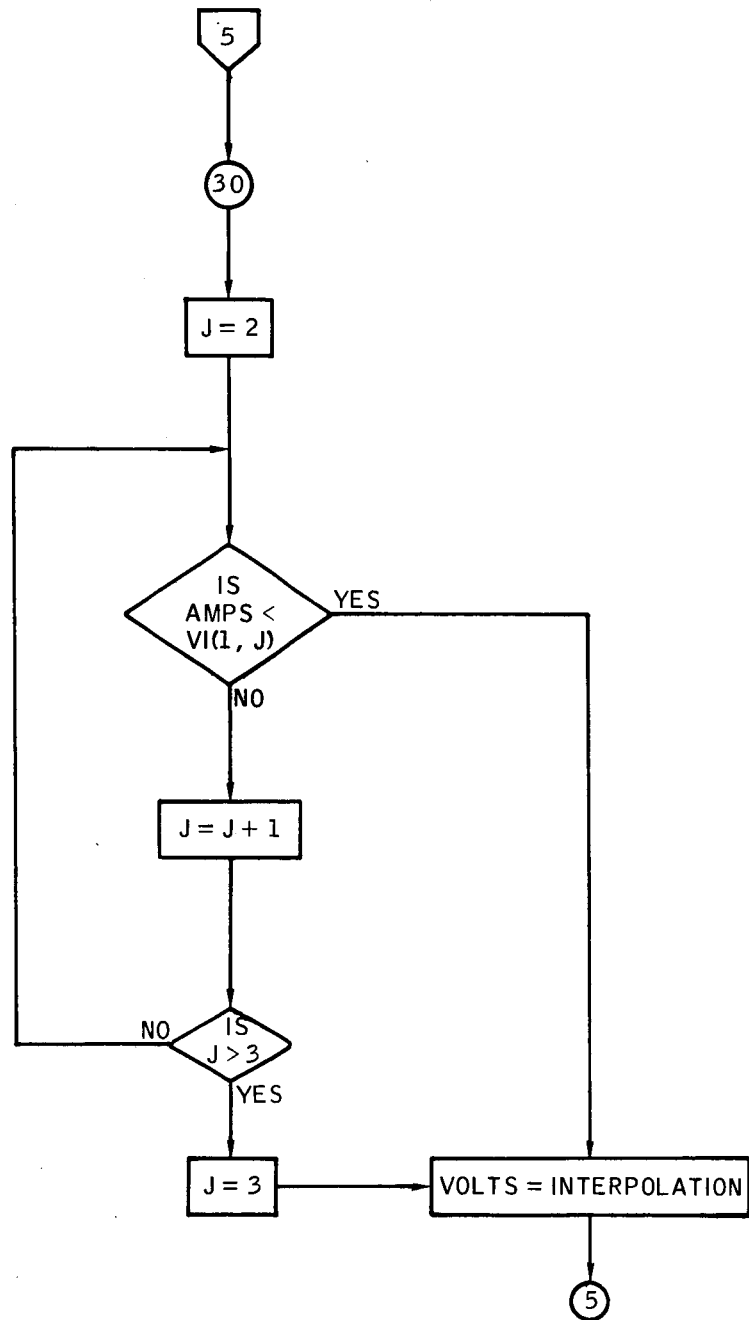
Flow Chart . - Continued.



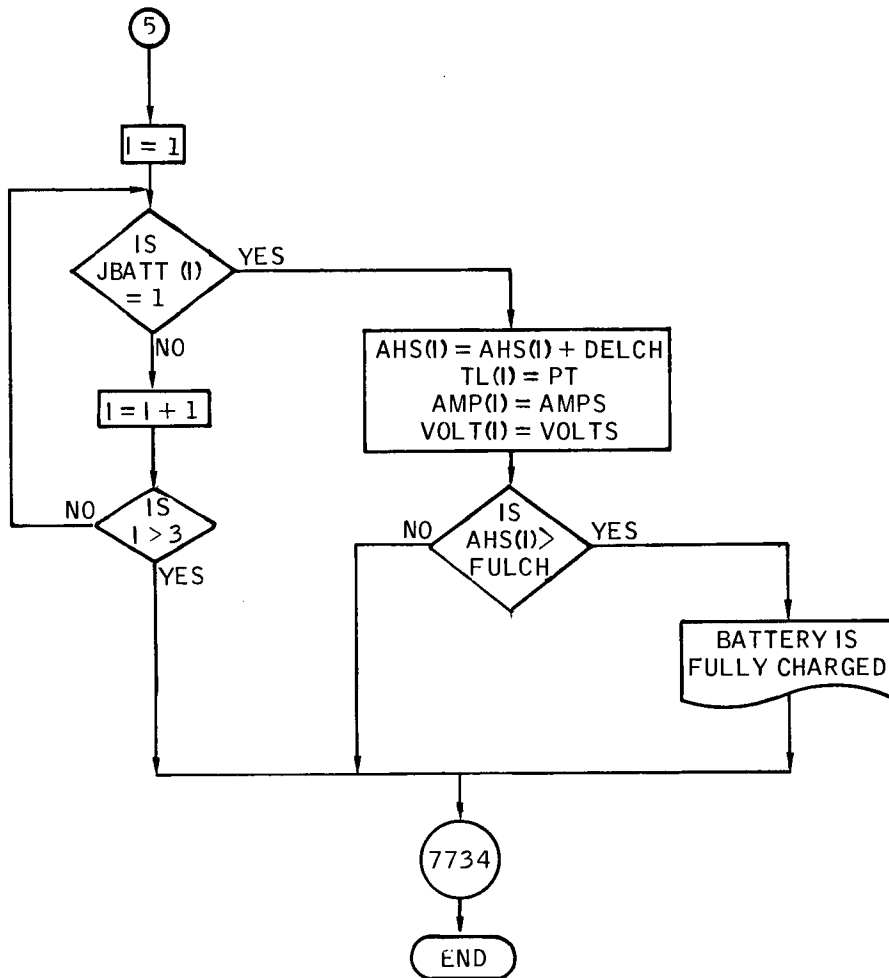
Flow Chart . - Continued.







Flow Chart - Continued.



Flow Chart . - Concluded.

7.0 BATTERY CHARGER MODEL COMPUTER PROGRAM LISTING

W FOR MAIN  
UNIVAC 1108 FORTRAN V LEVEL 2206 0016 F5018H  
THIS COMPILATION WAS DONE ON 30 JUN 69 AT 09:34:19

## MAIN PROGRAM

## STORAGE USED (BLOCK, NAME, LENGTH)

0001 \*CODE 0015/1  
0000 \*DATA 000404  
0002 \*BLANK 000000

## EXTERNAL REFERENCES (BLOCK, NAME)

0003 GROUPS  
0004 N1015  
0005 N1025  
0006 N1000  
0007 N1015

## STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000	000222 IF	0001	000256 10L	0000	000211 10UF	0000	000224 10ZF	0000	000231 110F
0000	000241 12F	0001	000014 120G	0001	000021 124G	0001	000026 130G	0001	000033 134G
0000	000261 14L	0001	000040 140G	0001	000056 147G	0001	000032 151L	0001	000057 155G
0001	000302 16L	0001	000065 161G	0001	000076 166G	0001	000104 174G	0001	000347 18L
0001	000167 186L	0001	000171 169L	0001	000114 20L	0000	000254 20ZF	0000	000257 203F
0001	000450 22L	0001	000152 24L	0001	000171 25L	0001	000647 251L	0001	000662 252L
0001	000675 253L	0001	000722 254L	0001	000754 255L	0001	001027 256L	0001	001053 257L
0001	001144 26L	0001	000267 265G	0001	001223 27L	0001	001332 277G	0001	001262 28L
0001	001337 29L	0001	000123 3L	0001	001374 30L	0001	000401 313G	0001	001465 32L
0001	000435 325G	0001	001504 34L	0000	000307 35F	0000	000447 401F	0001	001375 501G
0001	001455 526G	0001	001521 551G	0001	001526 555G	0001	001533 561G	0001	001540 565G
0001	001552 573G	0001	001557 577G	0001	000250 6L	0001	001653 621L	0001	001070 622L
0000	000324 66F	0001	001511 7734L	0001	000253 6L	0001	000366 87L	0000	000217 91F
0000	000314 72F	0001	001410 97L	0001	000163 A	0000	000022 AA	0000	000153 AF
0000	000156 AHD	0000	000125 AHS	0000	000157 AHST	0000	000003 AMP	0000	000207 AMPS
0000	000164 B	0000	000052 BB	0000	000171 C	0000	000160 CALC	0000	000114 CC
0000	000170 CP	0000	000201 CS15	0000	000177 CS11	0000	000200 CS14	0000	000206 DELCH
0000	000165 E	0000	000102 EE	0000	000167 F	0000	000106 FF	0000	000166 FT
0000	000154 FULCH	0000	000203 G	0000	000145 J	0000	000141 IS	0000	000162 J
0000	000122 JEATT	0000	000144 K	0000	000161 M	0000	000142 MANY	0000	000152 NCH
0000	000000 NCHRG	0000	000136 UNAM	0000	000155 UNAMS	0000	000146 UN1	0000	000133 ONT1M
0000	000143 PT	0000	000202 RE	0000	000174 T	0000	000151 TA	0000	000130 TD
0000	000017 TL	0000	000147 TLG	0000	000150 T15	0000	000111 VI	0000	000006 VOLT
0000	0000410 VOLTS	0000	000174 X1	0000	000176 X12	0000	000205 XY3	0000	000173 X1
0000	000175 X2	0000	000204 X3						

12

11

10

9

8

7

6

5

4

3

2

00100 1° C BATTERY CHARGER  
00100 2° C

```

00100 3* C
00101 4* DIMENSION NCHRG(3),AMP(3),VOLT(3),VLI(2,3)
00103 5* DIMENSION TLT(3),AA(2,3),BB(2,3),EE(2,2),FF(2,3),CC(3,3)
00104 6* DIMENSION JBATT(3),AHS(3),TD(3),ONTIM(3),ONAH(3)
00105 7* DATA VI,NCHRG/0.,40.,2.,2,37.,2,8.,0.,0,0,0/
00110 8* DATA AA,BB,CC,EE,FF/0.,2,3,2,7.,6,1,1,2.,0,0,0,2,3,4,5,6,8,15,0,0,0,0/
00110 9* 22,3,6,3,1,0,6,17,3,0,0,0,2,3,7,4,5,1,2,1,20,9,0,0,0,2,3,5,2,1,0,6,20,
00110 10* 3,77,0,2,3,6,1,1,5,1,20,1,1,4,0,12,3,6,5,1,8,3,20,1,2,2,0,2,3,7,3,
00110 11* 42,0,8,20,2,10,0,3,5,6,8,5,10,5,0,0,0,16,12,5,0,0,4,3,9,1,4,9,
00110 12* 54,7
00110 13* C
00110 14* C
00116 15* 75 READ(5,100)TL,ONTIM,AHS,TU,ONAH
00144 16* 100 FORMAT(3F10.3/3F10.3/3F10.3/3F10.3/3F10.3)
00145 17* READ(5,91)AMP,VOLT
00157 18* 91 FORMAT(3F10.3/3F10.3)
00160 19* DO 77 MANY=1,15
00163 20* READ(5,1)PT,JBATT
00172 21* 1 FORMAT(F10.3,3I2)
00173 22* DO 2 K=1,3
00176 23* I = K
00177 24* IF(JBATT(K).EQ.1)GO TO 3
00201 25* 2 CONTINUE
00203 26* WRITE(6,102)
00205 27* 102 FORMAT(25H CHARGER NOT IN OPERATION)
00206 28* GO TO 7734
00207 29* 3 ONT = ONTIM(1)
00210 30* TLD = ONT - TD(1)
00211 31* TLS = TLT(1)
00212 32* 23 IF(TLS.GE.ONT)GO TO 24
00214 33* NCHRG(1) = NCHRG(1) + 1
00215 34* WRITE(6,110)
00217 35* 110 FORMAT(39H THIS IS FIRST GET SOLUTION FOR CHARGER)
00220 36* TLS = ONT
00221 37* 24 TA = TLS - ONT
00222 38* NCH = NCHRG(1)
00223 39* IF(NCH.LE.5160 TO 188
00225 40* AF = .9
00226 41* GO TO 189
00227 42* 188 AF = 1.0
00230 43* 189 FULCH = AF * 40*
00231 44* ONAHS = ONAH(1)
00232 45* AHD = 40. - ONAHS
00233 46* AHS1 = AHS(1)
00234 47* CALC = AHS1 * .001
00235 48* 1E1CALC,GE,FULCH)GO TO 34
00235 49* C
00235 50* C
00235 51* C
00237 52* 1E1AHD,LT,0,0)GO TO 7734
00241 53* 1E1AHD,LT,2,0)GO TO 4
00243 54* 1E1AHD,LT,4,0)GO TO 8
00245 55* 1E1AHD,LT,7,0)GO TO 10
00245 56* 1E1AHD,LT,10,0)GO TO 14
00245 57* 1E1AHS1,GE,30,160 TO 14
00250 58* 13 WRITE(6,121)
00252 59* 12 FORMAT(28H MORE THAN 10 A-H DISCHARGED)
00255 60* GO TO 14

```

```

00256 41* 6 M=1
00257 60 TO 14
00260 43* 8 M=2
00261 64* 10 M=3
00262 45* 10 M=3
00263 46* 10 M=3
00264 47* C
00265 48* C
00266 49* C
00267 70* 14 DO 15 J=2,3
00268 71* IF (LT,AA(1,J,N)) GO TO 16
00269 72* 15 CONTINUE
00270 73* A = U.
00271 74* 16 A=1LU = AA(1,J,N) - AA(2,J,N) / (AA(1,J,N) - AA(1,
00272 75* 2J-1,M) + AA(2,J-1,N)
00273 76* C
00274 77* C
00275 78* C
00276 79* C
00277 80* 15 DO 17 J=2,3
00278 81* IF (LT,AA(1,J,N)) GO TO 18
00279 82* 17 CONTINUE
00280 83* B = BE(2,3,h)
00281 84* 18 R = 1LU - BB(1,J,N) * (BB(2,J,N) - BB(2,J-1,M)) - BB(
00282 85* 21,J-1,M) + BB(2,J-1,N)
00283 86* C
00284 87* C
00285 88* C
00286 89* C
00287 90* C
00288 91* C
00289 92* C
00290 93* C
00291 94* C
00292 95* DO 19 I=2,3
00293 96* IF (AMD,LI,FF(1,I)) GO TO 20
00294 97* 19 CONTINUE
00295 98* I=3
00296 99* 20 FT=(AMD-FF(1,I-1)) * (FF(2,I)-FF(2,I-1)) / (FF(1,I)-FF(1,I-1)) * FF(2,I)-
00297 100* 21)
00298 101* F = FT * E
00299 102* C
00300 103* C
00301 104* C
00302 105* DO 21 I=2,3
00303 106* IF (AMD,LT,CC(1,I)) GO TO 22
00304 107* 21 CONTINUE
00305 108* I=3
00306 109* 22 CP=(AMD-CC(1,I-1)) * (CC(2,I)-CC(2,I-1)) / (CC(1,I)-CC(1,I-1)) * CC(2,I)-
00307 110* 21)
00308 111* C = B * CP
00309 112* T = PT - ONT
00310 113* WRITE(6,401) T, F
00311 114* 401 FORMAT(5H1 = ,F7.2/5H F = ,F7.2)
00312 115* C
00313 116* C
00314 117* C
00315 118* X1 = (B-A)/E
00316 119*
00317 120*
00318 121*
00319 122*
00320 123*
00321 124*
00322 125*
00323 126*
00324 127*
00325 128*
00326 129*
00327 130*
00328 131*
00329 132*
00330 133*
00331 134*
00332 135*
00333 136*
00334 137*
00335 138*
00336 139*
00337 140*
00338 141*
00339 142*
00340 143*
00341 144*
00342 145*
00343 146*
00344 147*
00345 148*
00346 149*
00347 150*
00348 151*
00349 152*
00350 153*
00351 154*
00352 155*
00353 156*
00354 157*
00355 158*
00356 159*
00357 160*
00358 161*
00359 162*
00360 163*
00361 164*
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00345	119°	XY1 = A
00346	120°	X2 = (C-B)/(F-E)
00347	121°	XY2 = B - X2*E
00350	122°	CST1 = (B+A)*(E/2.0)
00351	123°	CST2 = (B+C)*(F-E)/2.0
00352	124°	CST3 = CST1 + CST2
00352	125°	C
00352	126°	C
00352	126°	C
00352	126°	C
00353	127°	IF (LT*TA) GO TO 734
00355	129°	AHD = FULCH - ONAHS
00356	130°	IF (AHD*LE.CST1) GO TO 251
00360	131°	IF (AHD*LE.CST5) GO TO 252
00362	132°	RL = AHD - CST5
00363	133°	G = (2.0*RE)/(C*4)*F
00364	134°	WRITE (6, 202) G
00367	135°	202 FORMAT ('HUG =', F11.7)
00370	136°	X3 = (4-C)/(6-F)
00371	137°	XY3 = C-X3*F
00372	138°	IF (TA*GT*E) GO TO 27
00374	139°	IF (1-G)*E) GO TO 25
00376	140°	DELCH = X1*((T*2)/2.0) + XY1*OT - X1*((TA*2)/2.0) - XY1*TA
00377	141°	AMPS = X1*OT + XY1
00400	142°	GO TO 30
00401	143°	251 IF (1-G)*E) GO TO 253
00403	144°	DELCH = FULCH - AHST
00404	145°	AMPS = *4
00405	146°	GO TO 30
00406	147°	252 IF (1-G)*F) GO TO 254
00410	148°	DELCH = FULCH - AHST
00411	149°	AMPS = *4
00412	150°	GO TO 30
00413	151°	253 DELCH = X1*((T*2)/2.0) + XY1*OT - X1*((TA*2)/2.0) - XY1*TA
00414	152°	AMPS = X1*OT + XY1
00415	153°	GO TO 257
00416	154°	254 IF (1-G)*E) GO TO 255
00420	155°	DELCH = X1*((T*2)/2.0) + XY1*OT - X1*((TA*2)/2.0) - XY1*TA
00421	156°	AMPS = X1*OT + XY1
00422	157°	GO TO 30
00423	158°	255 IF (TA*GT*E) GO TO 254
00425	159°	DELCH = X1*((E*2)/2.0) + XY1*E - X1*((TA*2)/2.0) - XY1*TA
00426	160°	DELCH = DELCH + X2*((T*2)/2.0) + XY2*OT - X2*((E*2)/2.0) - XY2*E
00427	161°	AMPS = X2*OT + XY2
00430	162°	GO TO 257
00431	163°	256 DELCH = X2*((T*2)/2.0) + XY2*OT - X2*((TA*2)/2.0) - XY2*TA
00432	164°	AMPS = X2*OT + XY2
00433	165°	257 CALC = AHST + DELCH
00434	166°	IF (CALC*GE.FULCH) GO TO 621
00436	167°	GO TO 622
00437	168°	621 DELCH = FULCH - AHST
00440	169°	AMPS = *4
00441	170°	622 GO TO 30
00442	171°	25 IF (T*GT*F) GO TO 26
00444	172°	DELCH = X1*((E*2)/2.0) + XY1*E - X1*((TA*2)/2.0) - XY1*TA
00445	173°	DELCH = DELCH + X2*((T*2)/2.0) + XY2*OT - X2*((E*2)/2.0) - XY2*E
00446	174°	AMPS = X2*OT + XY2
00447	175°	GO TO 30
00450	176°	26 IF (1-G)*F) GO TO 6



```

00457 1770 DELCH = X1*((1002)/2.) + X10E - X1*((1002)/2.) - X10TA
00458 1780 DELCH = DELCH + CST2
00459 1790 DELCH = DELCH + X3*((1002)/2.) + X130F - X3*((1002)/2.) - X130F
00455 1800 AMPS = X30T + X13
00456 1810 GO TO 30
00457 1820 27 IF (TA0T.F) GO TO 29
00461 1830 IF (T0T.F) GO TO 26
00463 1840 DELCH = X2*((1002)/2.) + X120F - X2*((1002)/2.) - X120TA
00464 1850 AMPS = X20T + X12
00465 1860 GO TO 30
00466 1870 20 IF (T0T.GIT) = 4
00470 1880 DELCH = X2*((1002)/2.) + X120F - X2*((1002)/2.) - X120TA
00471 1890 DELCH = DELCH + X3*((1002)/2.) + X130F - X3*((1002)/2.) - X130F
00472 1900 AMPS = X30T + X13
00473 1910 GO TO 30
00474 1920 24 IF (T0T.GIT) = 6
00476 1930 DELCH = X3*((1002)/2.) + X130F - X3*((1002)/2.) - X130TA
00477 1940 AMPS = X30T + X13
00477 1950 C
00477 1960 C
00500 1970 30 DO 96 J = 203
00503 1980 IF (AMPS.L1.VILL.DJ) GO TO 97
00505 1990 96 CONTINUE
00507 2000 J = 3
00510 2010 97 VOLTS = (AMPS - V1((1,J-1)) + V1(2,J-1)) / (V1(1,J-1) - V1(1,J-1))
00514 2020 20 WRITE(203) A,B,C,E,F,DELCH,TA,PT,CP
00524 2040 903 FORMAT(4H0A = F11.7//1X3HB = F11.7//1X3HC = F11.7//1X3HE = F11.7//
00524 2050 21X3HF = F11.7//1X7HDELCH = F11.7//1X4HIA = F11.7//1X4HFI = F11.7//
00524 2060 31X4HCP = F11.7)
00524 2070 C
00524 2080 C
00524 2090 C
00525 2100 C
00530 2110 IF (BAT11) EQV1 GO TO 32
00532 2120 31 CONTINUE
00534 2130 GO TO 7734
00535 2140 32 AM5(1) = AM5(1) + DELCH
00536 2150 TL(1) = PT
00537 2160 AMPI1 = AMPS
00540 2170 VOL(1) = VOLTS
00541 2180 IF (AM5(1).LT.FULCH) GO TO 7734
00543 2190 34 WRITE(6,35)
00545 2200 35 FORMAT(25H1BATTERY IS FULLY CHARGED)
00546 2210 7734 WRITE(6,60) PT, TL, AM5, TU, UNTIN
00571 2220 WRITE(6,92) AMP, VOLT
00603 2230 92 FORMAT(1X5H AMPS,1UA,3F20.5//1X,6H VOLTS,9X,3F20.5)
00604 2240 60 FORMAT(13H0PRESENT TIME,1F12.5//130X,1HA20X,1HB,20X,1HC,1A,14H LAS
00604 2250 21 GET SOLN,1X3F20.5//1X,11H A-W STATUS,4X,3F20.5//1X,15H LAST DISCH
00604 2260 3ARGE,3F20.5//1X,8H ON TIME,7X,3F20.5)
00605 2270 77 CONTINUE
00607 2280 *DIAGNOSTIC* THE RETURN STATEMENT IS ILLEGAL IN A MAIN PROGRAM. IT WAS CHANGED TO STOP.
00610 2290 RETURN
00610 2290 END

```

END OF UNIVAC 1108 FORTRAN V COMPILATION. 1 \*DIAGNOSTIC MESSAGE(S)

## 8.0 SAMPLE CASE

The battery charger output characteristic is presented in figure 8-1 as a function of the battery initial conditions. The initial conditions are given in table 8-I. Note from figure 8-1 that it takes 5.92 hours to recharge the CSM entry and postlanding battery which has been depleted by only 4 A-h. This recharge time is caused primarily by the very long time period of 22 hours from the time of last discharge to the time the battery charger was put on the battery. Very low starting and peak charger currents are also results of this long period of time between battery use and battery recharging.

TABLE 8-I.- ENTRY AND POSTLANDING BATTERY

## INITIAL CONDITIONS

Conditions tested	Result of test
Battery A-h status at time of charging . . . . .	36.0
Full charge A-h rating of battery . . . . .	40.0
Time from end of last discharge, hr . . . . .	22.0

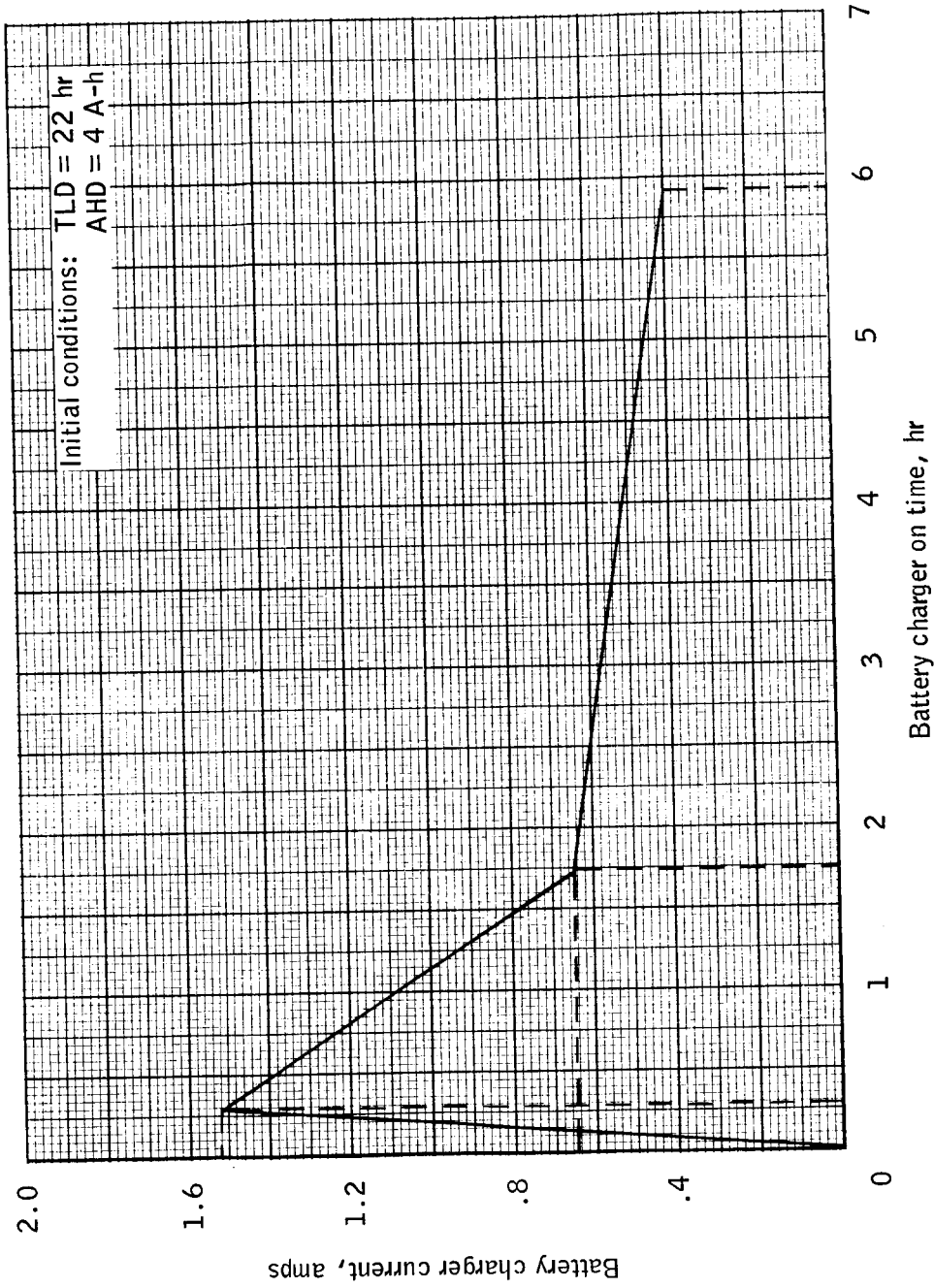


Figure 8-1. - Battery charger output profile.

9.0 BATTERY CHARGER MODEL DESIGN DATA

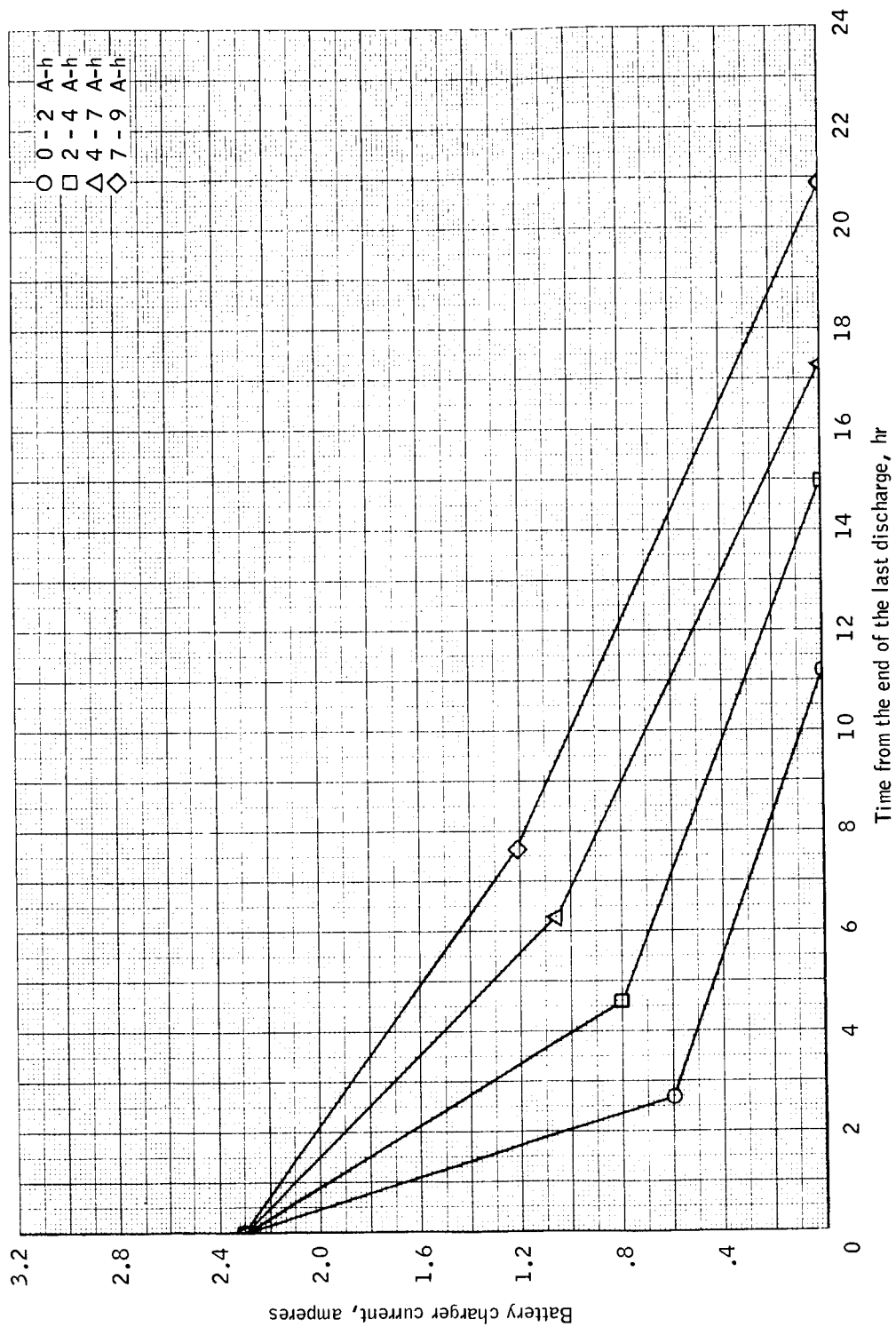


Figure 9-1.- Battery charger starting current co-ordinate A.

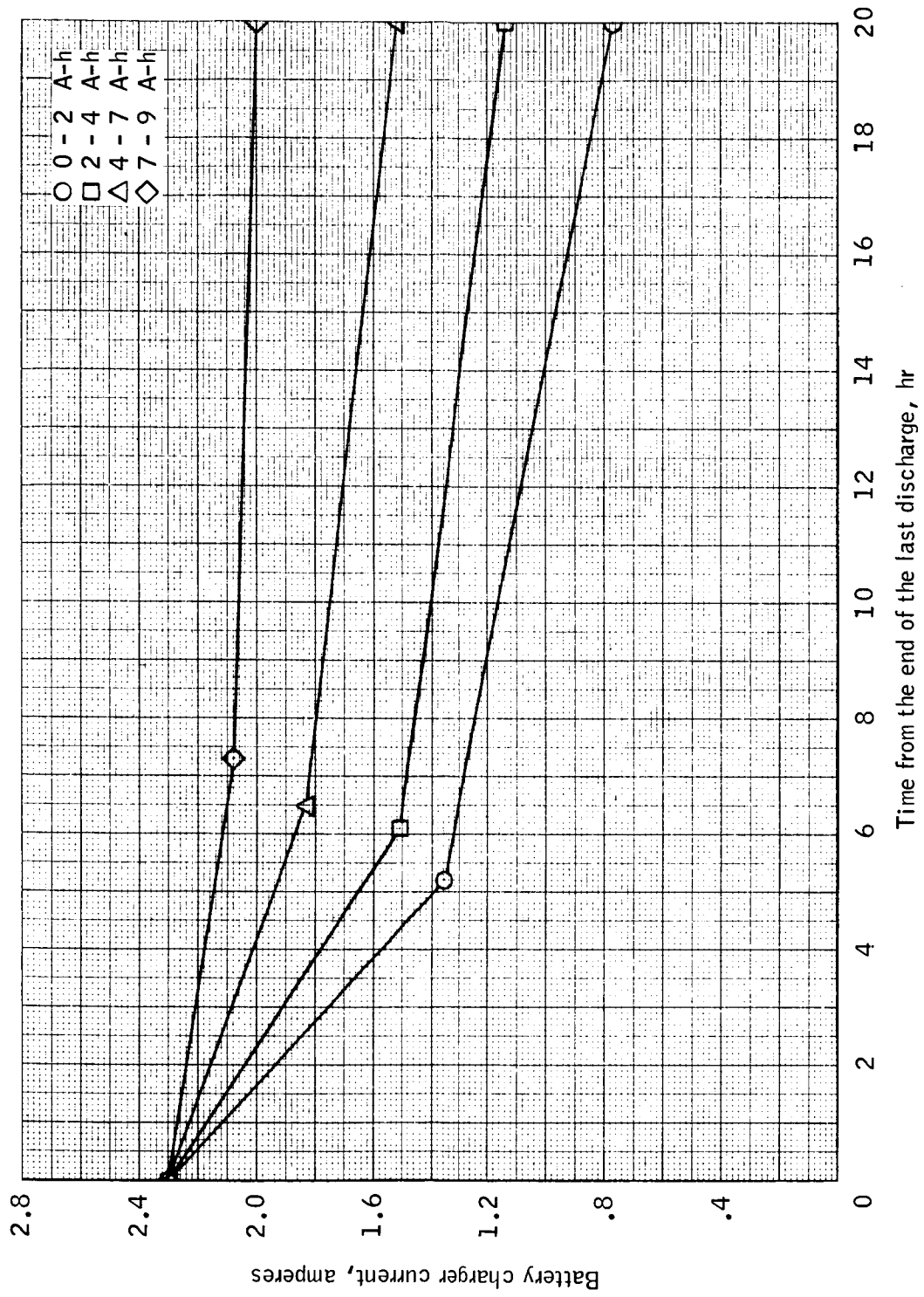


Figure 9-2.- Battery charger peak output current co-ordinate B.

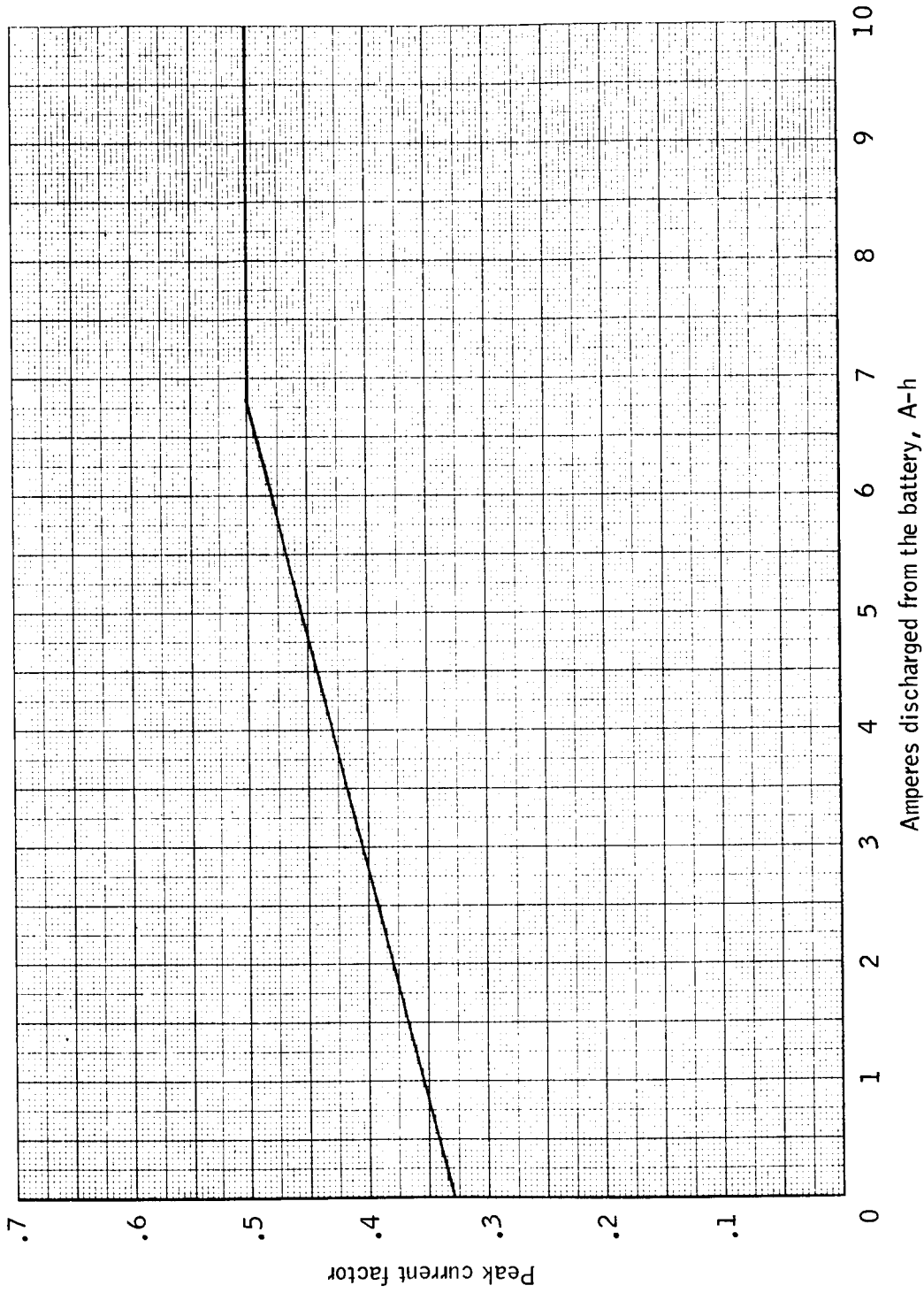


Figure 9-3.- Battery charger output current co-ordinate C peak current factor.

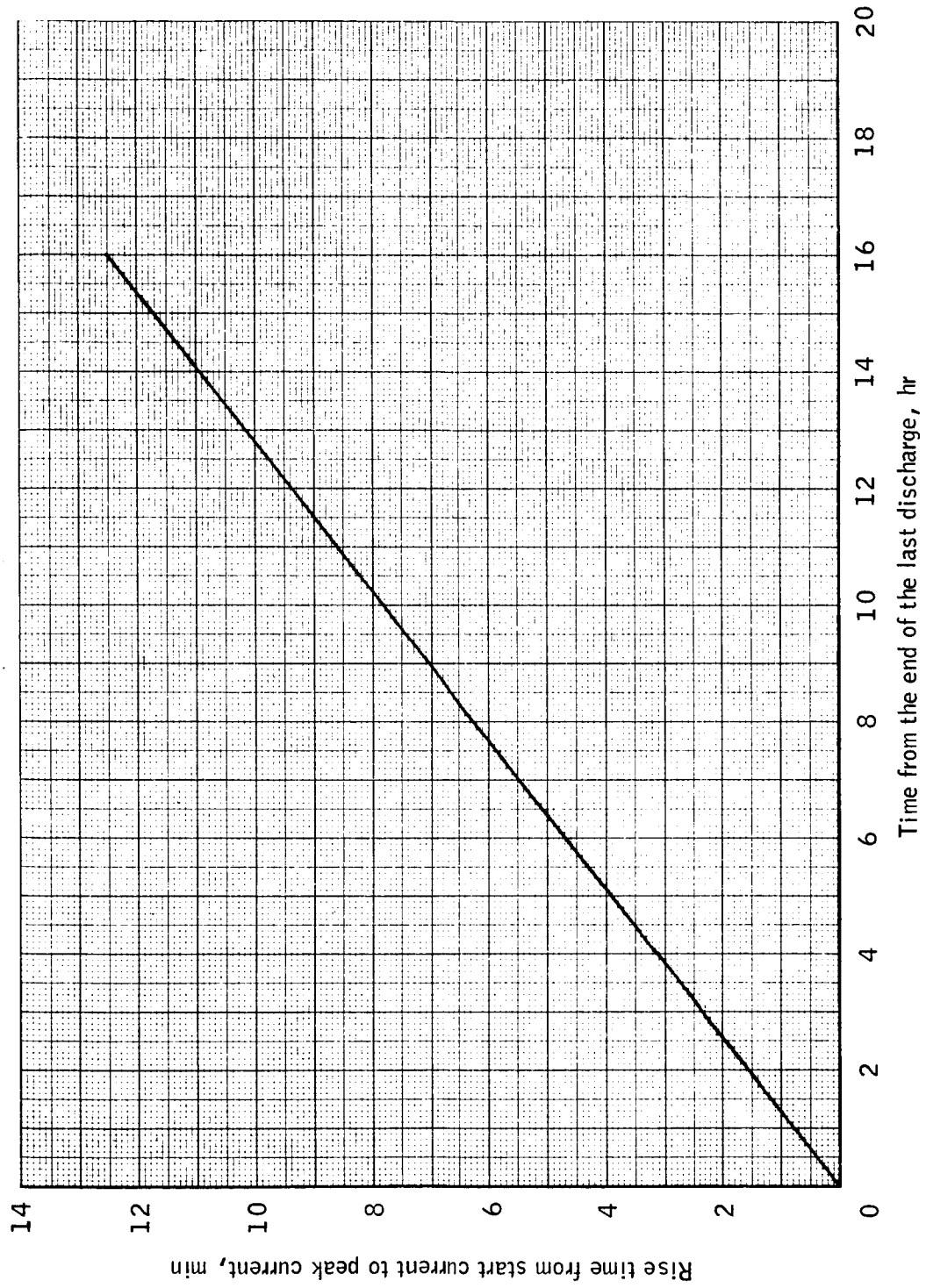


Figure 9-4.- Battery charger output current rise time from the starting current level to the peak current level co-ordinate E.



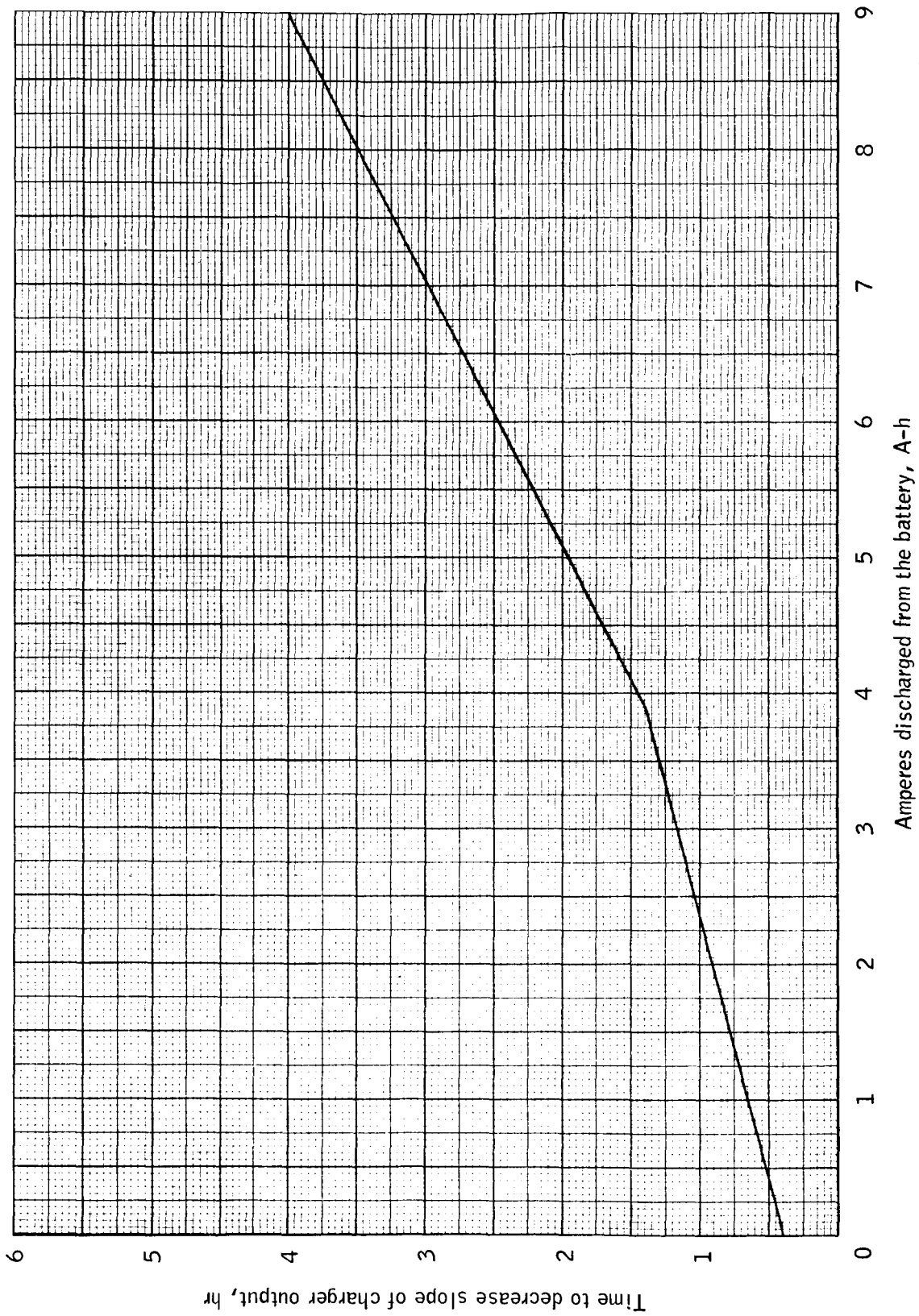


Figure 9-5. - Battery charger output co-ordinate F.

REFERENCES

1. Charge - Discharge Testing of the Entry and Post-Landing Battery and Spacecraft Battery Charger. MSC/IESD document 21-15, Revision A.
2. Spacecraft Operational Data Book, SNA-8-D-027(I) Rev I, Electrical Power Subsystem.